Investigation of precipitation processes with RAMS and observations

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Theme of work…

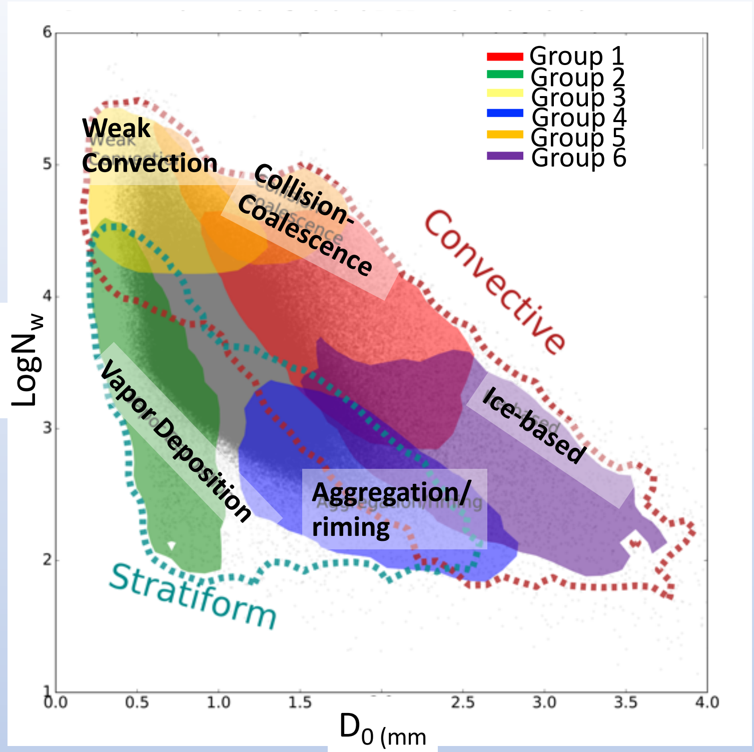
- There are still major uncertainties as to how model simulated drop size distributions (DSDs) compare to observed DSDs

- We can take advantage of extensive DOE databases on ground based drop size distributions by comparing to model-simulated DSDs

- Validation of DSDs relates to model microphysical fields that shape the DSDs and are strongly coupled to cloud dynamics

Goals

- Dolan et al. (2018) applied principal component analysis (PCA) to global surface disdrometer dataset
  - PCA provides a simplified statistical analysis framework for studying precipitation variability
  - Identified six groups with common DSD characteristics
  - Inferred microphysical origins from radar data



Leverage the PCA framework to statistically analyze precipitation physics using large databases of observations and model simulations:

1) Assess ability of models to capture physical variability of observed DSDs

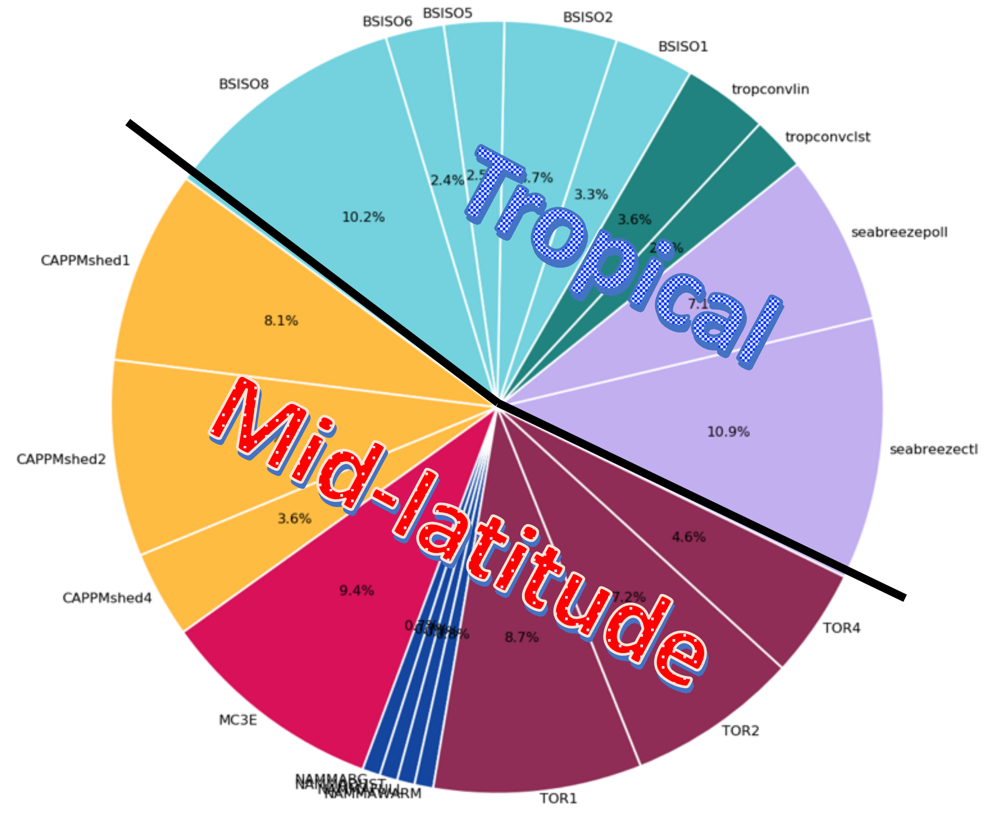
2) Connect cloud processes to surface DSDs by interrogating model output

RAMS

Observations

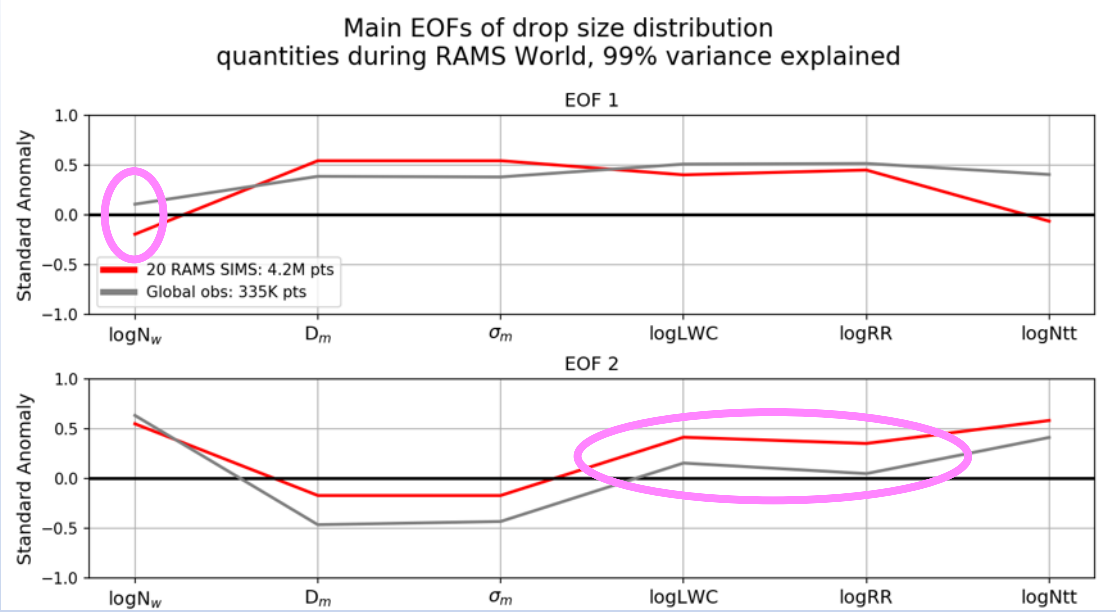
RAMS simulation database:

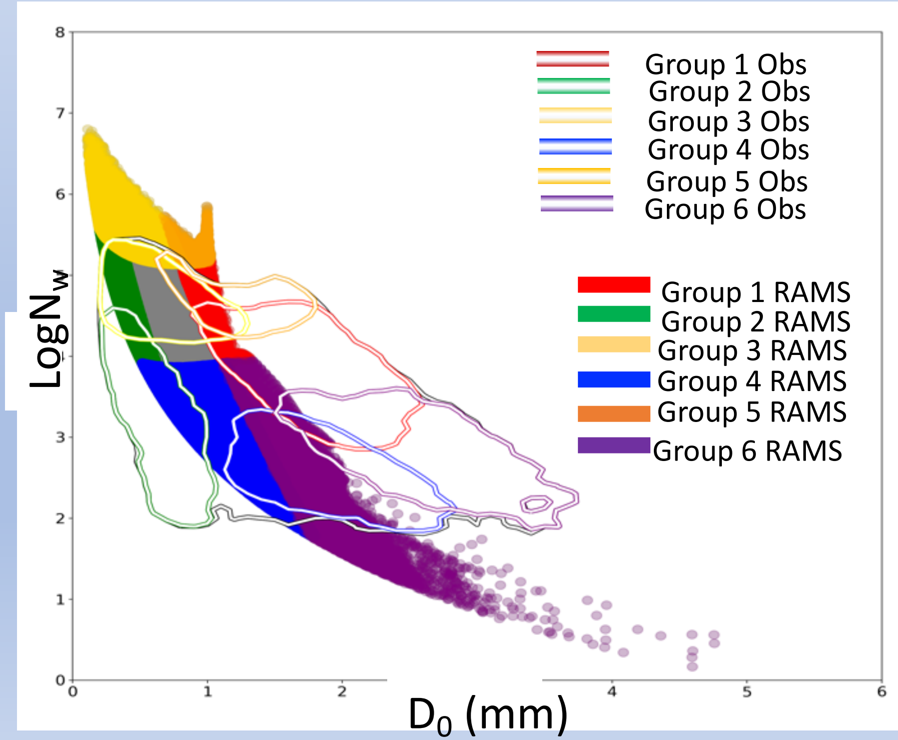
- RAMS has been used for a wide variety of studies -> large database of different types of precipitation and environments to tap into:
  - Sea breezes (Grant)
  - BSISO (Toms)
  - Supercells (Freeman)
  - Oceanic convection (Saleeby)
  - Mid latitude MCSs (Marinescu)
  - Approximately 50/50 tropical, mid-latitude
  - Still missing some types and environments??
- RAMS 2-moment bulk microphysics (Saleeby and van den Heever 2013)
  - Extend to bin microphysics (HUCM SBM in RAMS)
- Calculate DSD parameters at surface (D_0, N_w, μ, LWC, RR, N_t) and apply PCA



RAMS PCA Results

- Nearly the same 1st two EOFs with model and observations databases
- There are some differences:
  - N_w and N_t in EOF 1 are not the same
  - Differences in LWC/RR variability in EOF2





- Six groups reside in same relative (but not absolute) regions of $\log N_w$-D_0 space

- Model is largely capturing variability in DSD seen by disdrometer dataset
- Pursue microphysical links to groups with model simulations

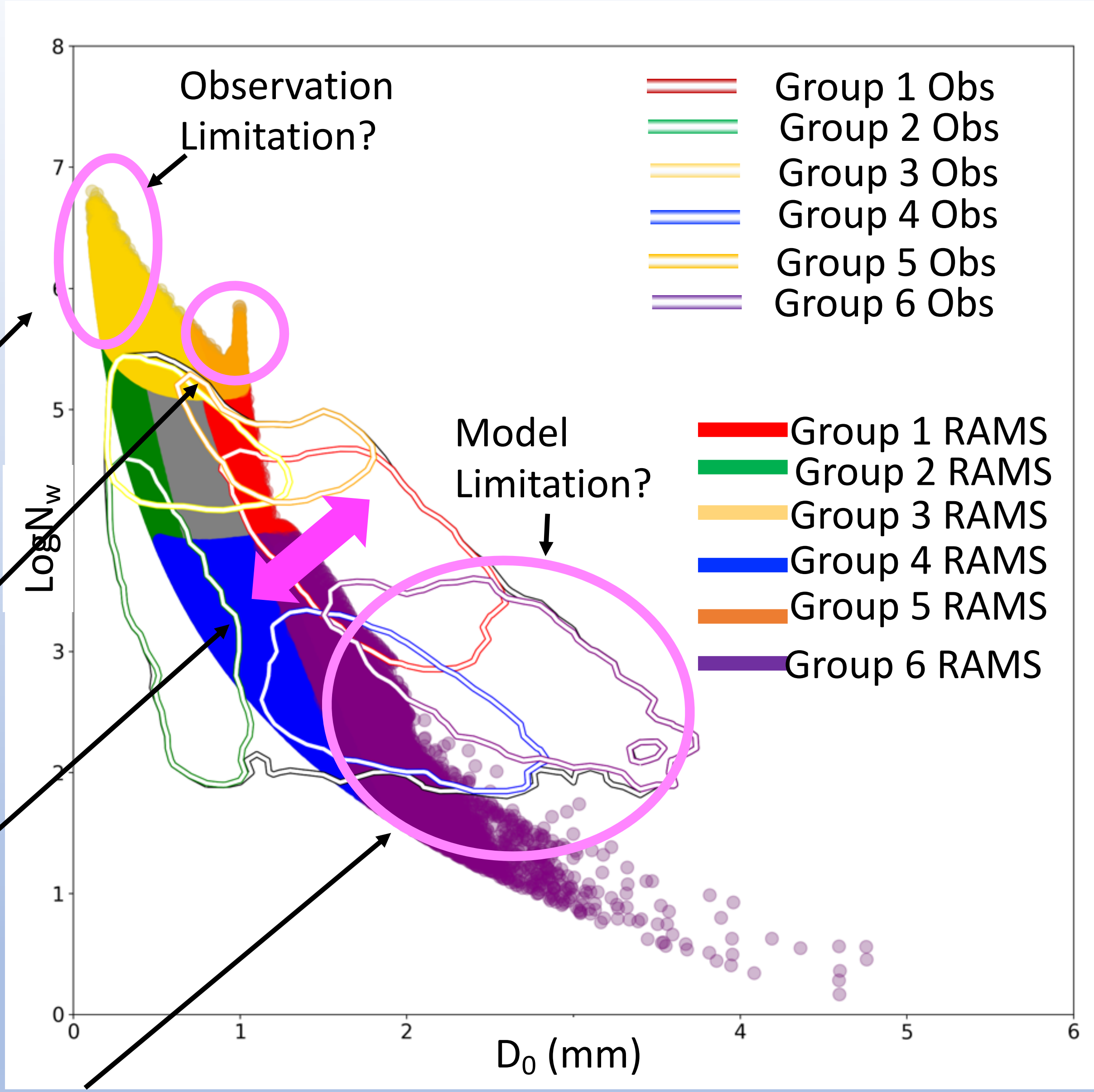
RAMS: PCA Results

Digging a little deeper….

- Low D_0, high N_w maybe be detection limit of disdrometers

- Prominent peak of high concentrations at mean diameters near 1 mm

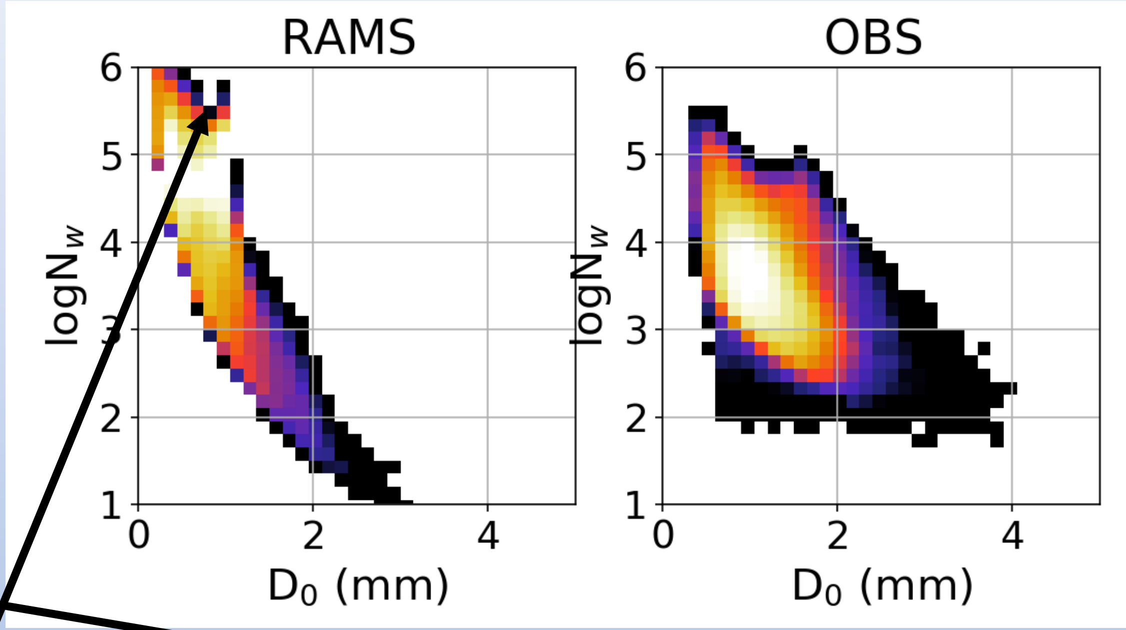
- Simulations live on a fairly narrow space
  - Constraints of assumptions (e.g. fixed shape parameter in 2 moment bulk?)

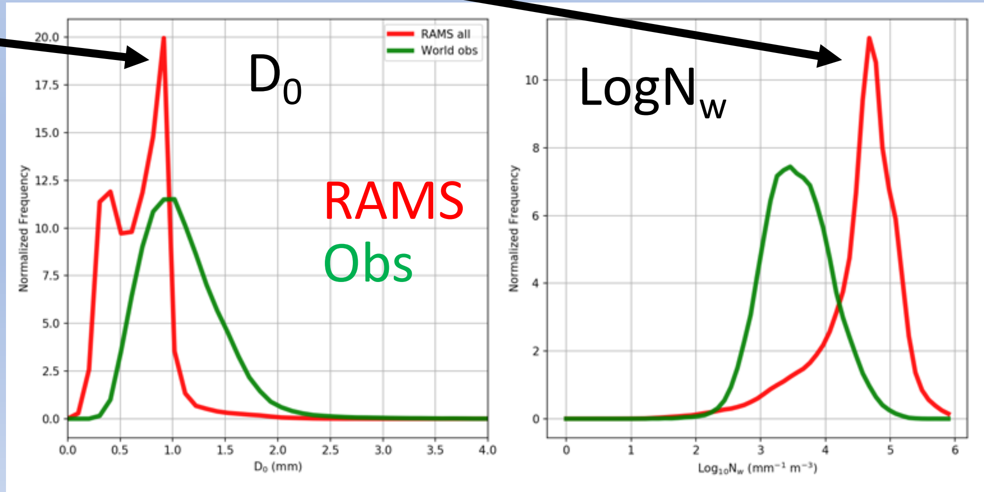


- Higher concentrations of bigger drops limitation of model

RAMS DSD Comparisons

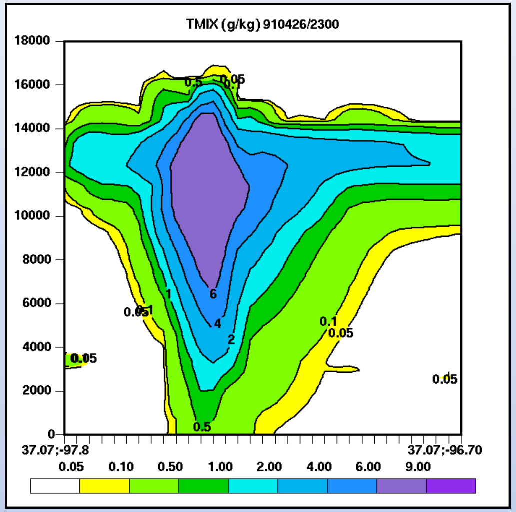
- Sims more narrowly distributed
  - Imposed constraints?
- Most frequent simulation $\log(N_w)$ values are higher (higher number concentrations)
  - Maybe disdrometer detection limit?
- Conspicuous peak at D_0~ 1 mm
- These results are independent of characteristics of the simulation



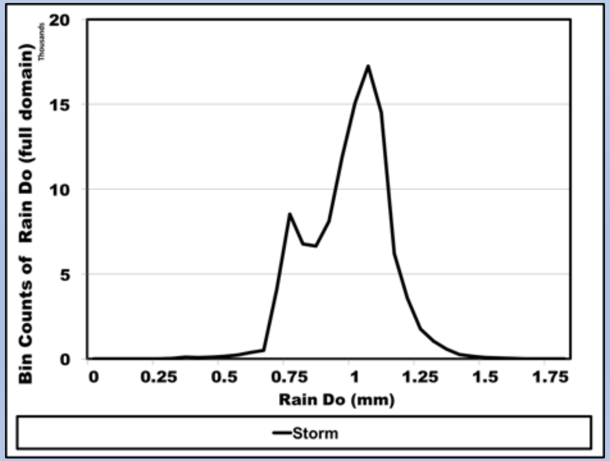


Exploring RAMS DSD:

Supercell Thunderstorm

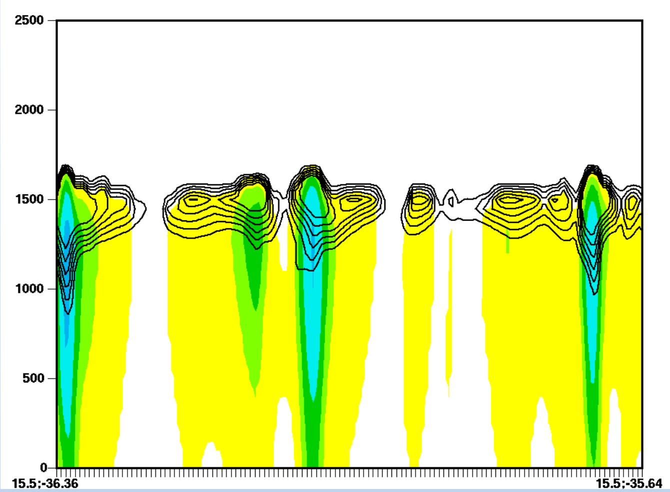


- Large mixing ratios, heavy precip

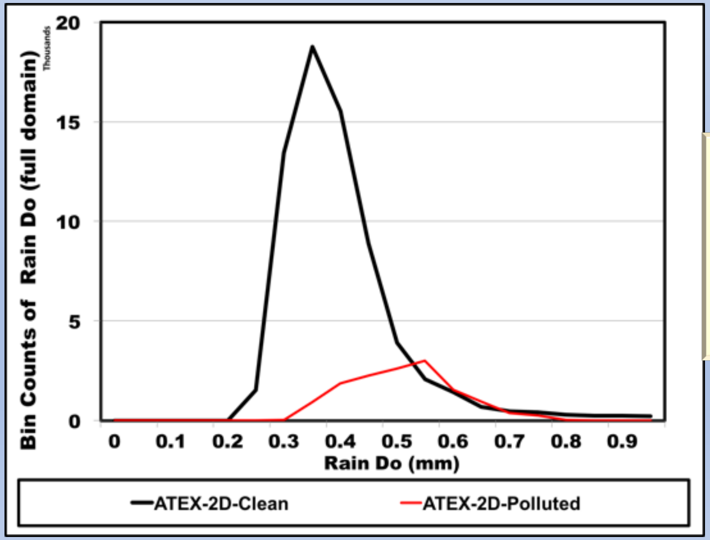


- **Frequency peak around 1 mm for deep convection and high LWC.**

2D ATEX Stratocumulus



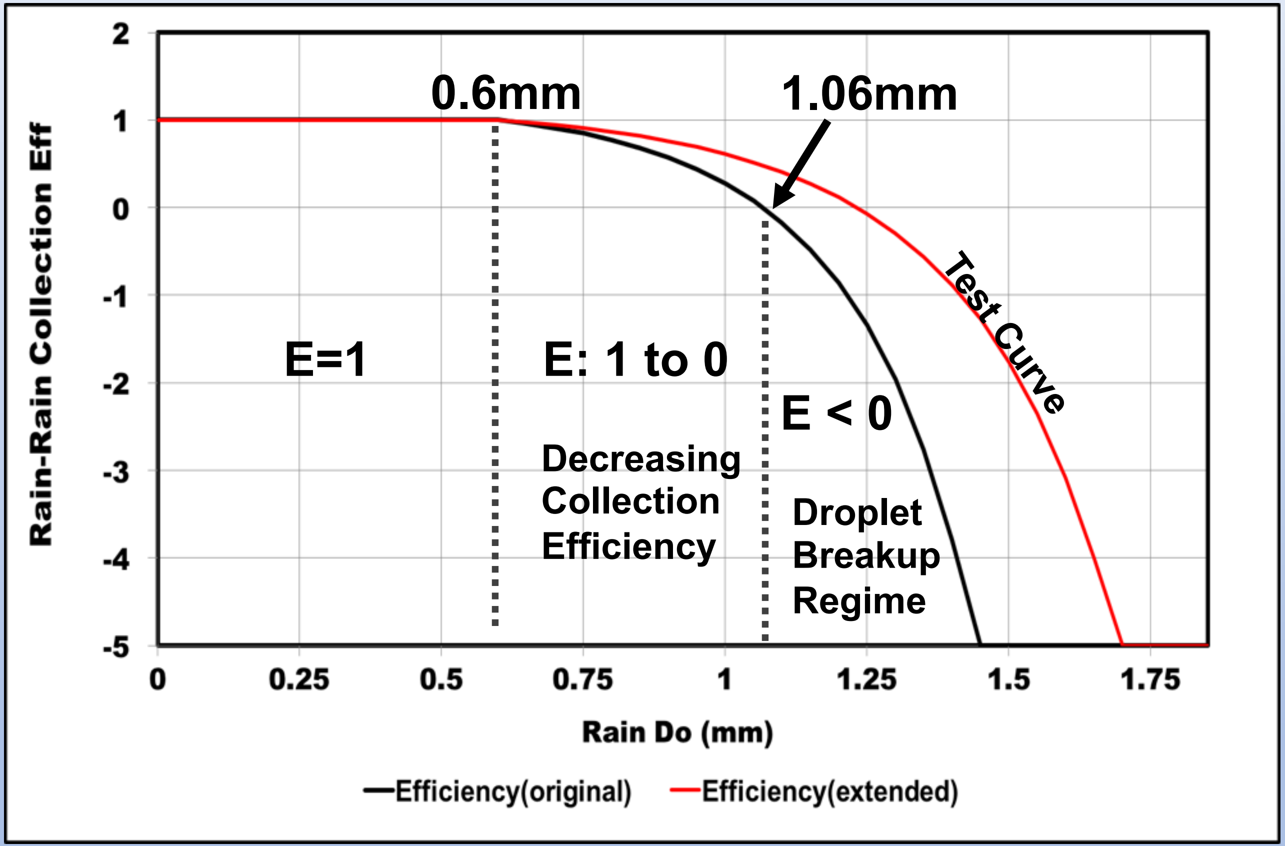
- Small mixing ratios, low LWC, barely raining at surface



- **Frequency peak varies for rain drops in shallow clouds and low LWC.**

The Problem with Drop Breakup

Rain Drop Self-Collection Efficiencies



Verlinde and Cotton (1993)

- Large drops are forced to breakup, increasing number concentration and push mean diameter back to equilibrium size (where E=0)
  - Likely occurs in steady state rain
  - In nature (e.g. disdrometer observations), larger drops are achieved more frequently than are allowed
- Drop breakup has significant feedbacks to storm dynamics, structure, initiation, evolution, cold pools, precipitation (Morrison et al. 2012)

Parameterization of rain drop breakup

The Problem with Drop Breakup

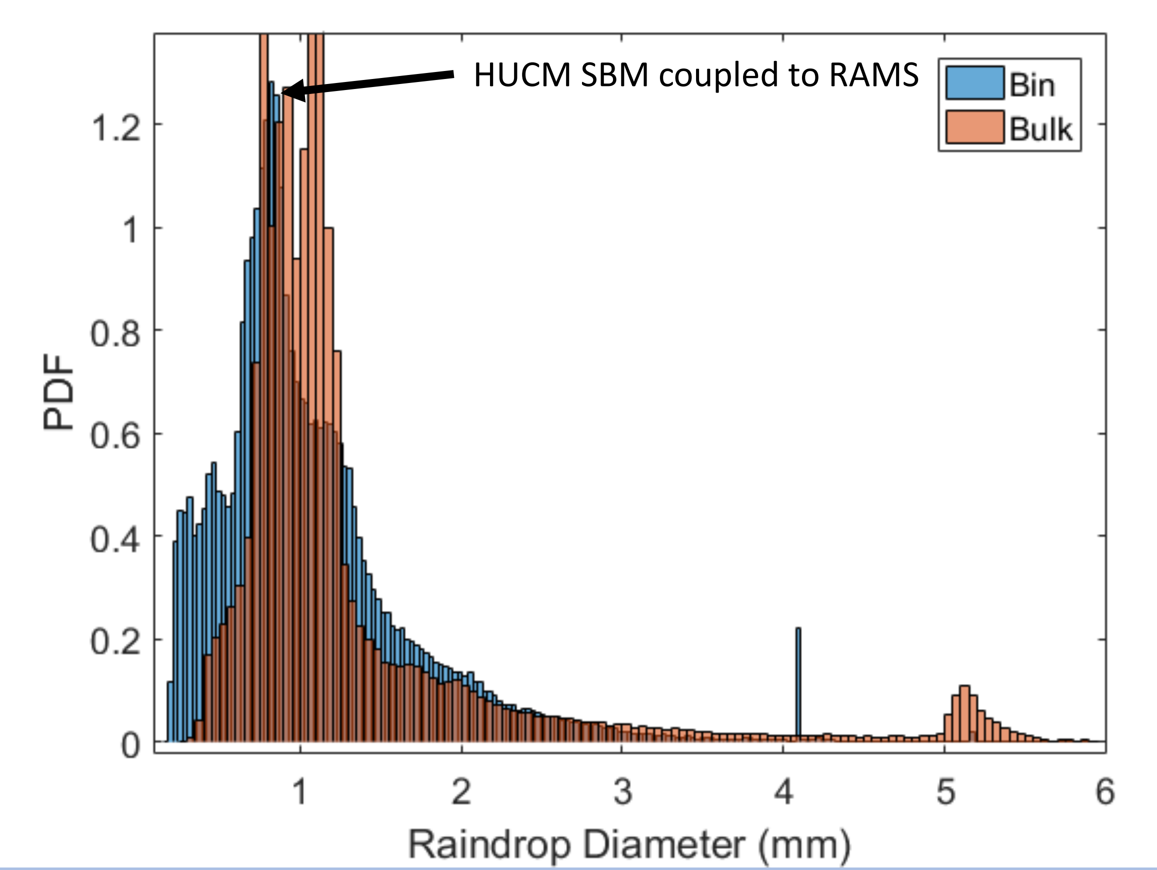
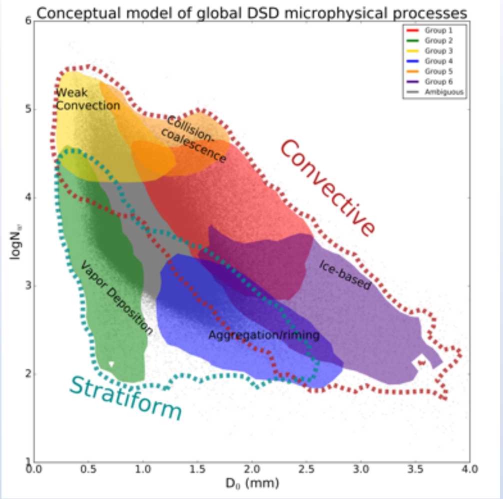


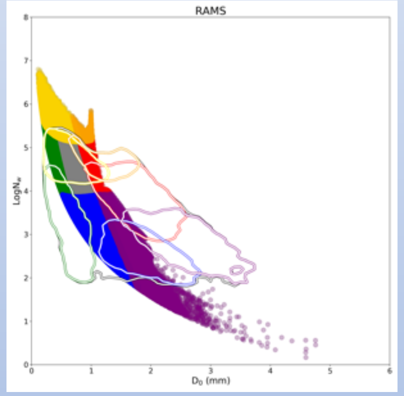
Figure courtesy of Adele Igel, UC-Davis

- Many microphysics schemes represent collisional rain drop breakup similar to Verlinde and Cotton (1993)(e.g. RAMS, Morrison)
  - Alternatives?
- Same issue using HUCM bin microphysics parameterization within the RAMS model

In summary….

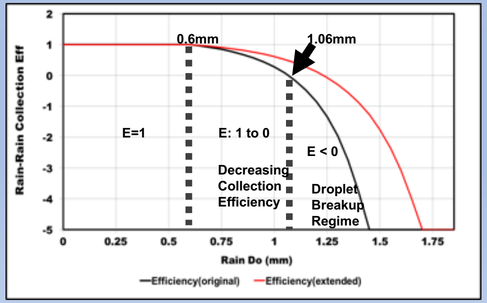


- Rain DSDs fall into 6 Groups with microphysical origins based on PCA



- Model produces same relative modes of variability on macro scale -> contextualize observations

- Models lack breadth in DSDs seen by observations
  - Overaggressive drop breakup
    - *Do we understand drop breakup enough to accurately parameterize it?*

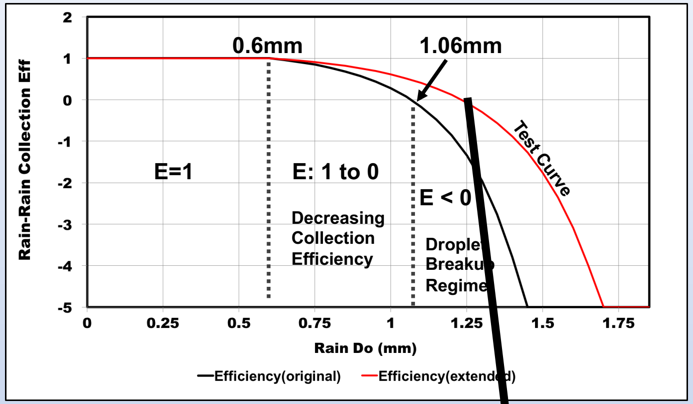


Next Steps

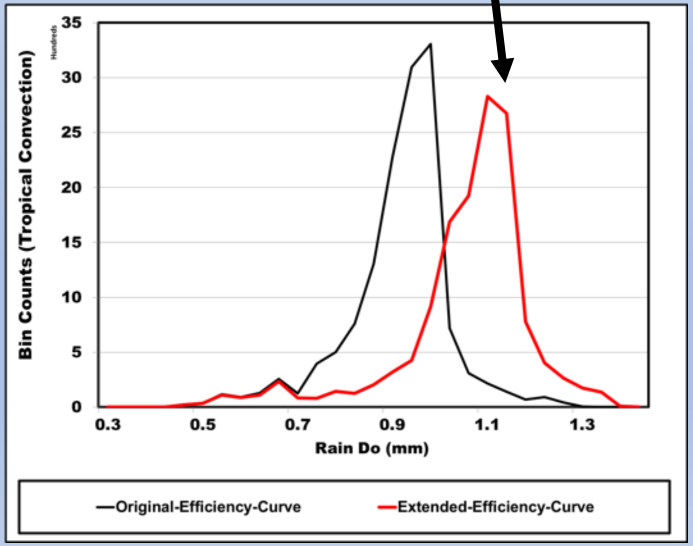
- Analyze mircrophysical process rates from RAMS in relation to DSD Groups
- Explore the influence of shape parameter on model’s ability to simulate DSD
  - Including in bin simulations where it can evolve
- Investigate collisional drop breakup parameterization

Come see our poster! #97 in Poster session A2!

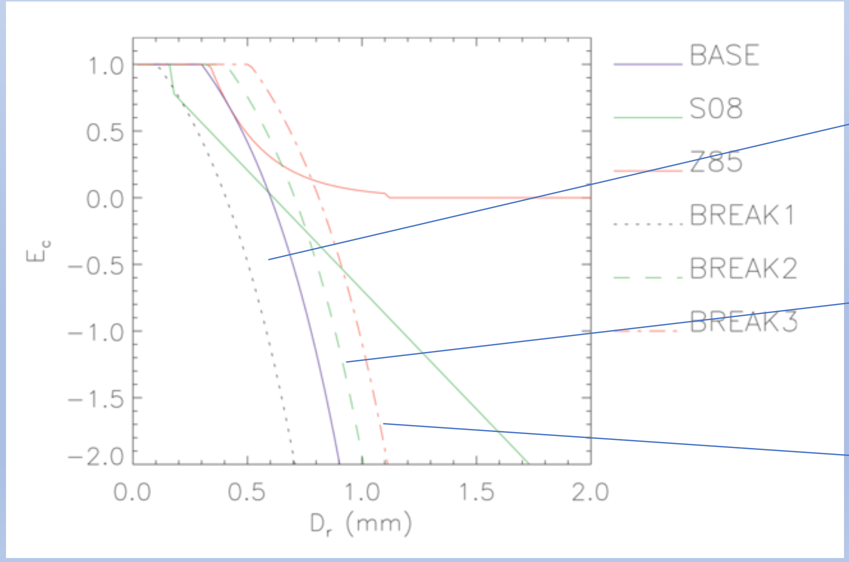
The Problem with Drop Breakup

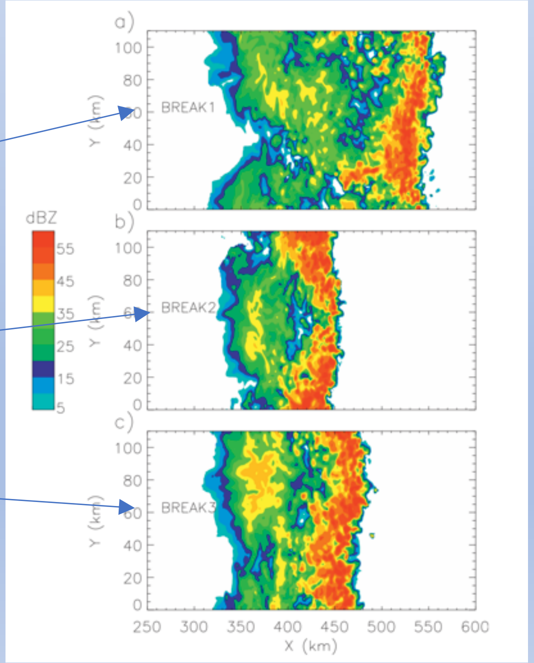


- Shifting the Efficiency curve shifts the equilibrium diameter



- Implications and feedbacks:
  - Impact on evaporation, cold pools, precipitation, storm structure and evolution [Morrison and Milbrandt 2011, Morrison et al. 2012, van Weverberg et al. 2012]





From Morrison et al. 2012